1.2 VAPOR PRESSURE, BOILING POINT, AND ENTHALPY OF VAPORIZATION

1.2.1 VAPOR PRESSURE

Summary

Recommended values for the vapor pressure of sodium are given in Table 1.2-1 as a function of temperature. They are calculated from an equation given by Browning and Potter.[1] The equation from Browning and Potter has been recommended because their analysis (1) is based on a careful assessment of the available experimental data, (2) is consistent with recommended values for the critical pressure, (3) is in good agreement with recommendations from other recent assessments, and (4) provides a simple three-term equation for the entire temperature range. This equation for the natural logarithm of the vapor pressure over saturated liquid sodium (liquid sodium in equilibrium with its vapor) is

$$\ln P = 11.9463 - 12633.73/T - 0.4672 \ln T \, , \qquad (1)$$

where P is in MPa and T is in K. This recommended equation is based on Browning and Potter's analysis of the available data[2-10] in the 864 to 2499 K temperature range. It gives a temperature of 2503.7 K for the critical pressure of 25.64 MPa.[8] Figures 1.2-1 and 1.2-2 show the recommended values of the vapor pressure over saturated liquid sodium as a function of temperature and the natural logarithm of the vapor pressure as a function of inverse temperature. Uncertainty bands have been included in Fig. 1.2-1. Estimates of the uncertainties as a function of temperature are given in Table 1.2-2.

Discussion

The recommended equation for the vapor pressure of saturated sodium is one of two equations from the analysis by Browning and Potter.[1] It is based on their analysis of nine sets of data from 864 to 2499 K, as shown in Table 1.2-3. The other equation given by Browning and Potter is a fit to the experimental data from 864 to 2361 K. This equation, preferred by Browning and Potter and given as Eq. (6) in Reference 1, is:

$$\ln P = 11.2916 \pm 0.5077 - (12532.694 \pm 87.141)/T - (0.3869 \pm 0.0600) \ln T \, , \qquad (2)$$

where P is in MPa and T is in K. Browning and Potter recommended this equation, which fit data only to 2361 K, rather than their fit to all the available data to the critical pressure because the Bhise and Bonilla[8] data above 2361 K were based on temperatures determined indirectly rather than

Table 1.2-1 Vapor Pressure of Saturated Sodium

Temperature (K)	**Pressure (MPa)**	**Pressure (atm)**
400	(1.80×10^{-10})*	(1.78×10^{-9})
500	(8.99×10^{-8})	(8.87×10^{-7})
600	(5.57×10^{-6})	(5.49×10^{-5})
700	(1.05×10^{-4})	(1.04×10^{-3})
800	(9.41×10^{-4})	(9.28×10^{-3})
900	5.147×10^{-3}	5.080×10^{-2}
1000	1.995×10^{-2}	0.1969
1100	6.016×10^{-2}	0.5937
1200	0.1504	1.485
1300	0.3257	3.214
1400	0.6298	6.216
1500	1.113	10.98
1600	1.828	18.04
1700	2.828	27.91
1800	4.161	41.06
1900	5.870	57.93
2000	7.991	78.86
2100	10.55	104.1
2200	13.57	133.9
2300	17.06	168.4
2400	21.03	207.5
2500	(25.47)	(251.3)
2503.7	(25.64)	(253.1)

*Parentheses indicate extrapolated beyond range of experimental data.

Table 1.2-2 Estimated Uncertainty in Values of Sodium Vapor Pressure Calculated from Eq. (1)

Temperature Range (K)	**Vapor Pressure (P, MPa)**	**Uncertainty (%)**
400 - 600	$\ln P = 11.9463 - 12633.73/T - 0.4672 \ln T$	25 - 9
600 - 864		6 - 4
864 - 1500		3
1500 - 2000		4
2000 - 2500		5

Table 1.2-3 Vapor Pressure Data Fit by Browning and Potter

Author	Date	Temperature Range (K)	Ref.
Bohdansky et al.	1967	1116 - 1390	2
Schins et al.	1971	1116 - 1390	3
Achener & Jouthas	1966	882 - 1228	4
Bowles & Rosenblum	1965	1072 - 2154	5
Makanski et al.	1955	893 - 1408	6
Stone et al.	1966	1140 - 1665	7
Bhise & Bonilla	1976	1255 - 2499	8
Sowa	1963	1173 - 1663	9
Vinogradov & Voljak	1966	864 - 1160	10

from thermocouple measurements. Both equations give temperatures of about 2503 K for the critical pressure of 25.64 MPa. Vapor pressures calculated with the two equations given by Browning and Potter are almost identical. Greatest deviations are 1.5% near the critical temperature, as shown in Fig. 1.2-3. Figure 1.2-3 shows deviations of other equations from the recommended equation, Eq. (1), expressed as a percent. The deviation is defined as

$$\frac{[\ P(CALC)\ -\ P(Eq.\ 1)\ ]\ 100\%}{P(Eq.\ 1)}\quad .$$

The equation based on the fit to the data set that includes the high temperature Bhise and Bonilla data (Eq. [10] in Reference 1) has been selected rather than the one for the lower temperature range because the vapor pressures in the region of the critical point are required for the calculation of other thermodynamic properties and for calculations under severe accident conditions.

Comparisons have been made of the vapor pressure calculated from the recom-mended equation with equations recommended by Bystrov et al.,[11] Vargaftik and Voljak,[12] Fink and Leibowitz,[13-15] and Thurnay.[16] For the temperature range of 864 to 2500 K, agreement was excellent as shown in the graph of vapor pressures in Fig. 1.2-4. Differences between vapor pressures calculated from the recommended equation (Eq. [1]) and those calculated with other equations, expressed as a percent are shown in Fig. 1.2-3.

Recently, Binder[17] reported high temperature vapor pressures as well as values for critical parameters based on his experimental PVT measurements at high pressure and temper-ature. He obtained the critical parameters and the vapor pressure on the saturation curve by extrapolation of his results for superheated sodium. He gives 2485 ± 15 K for the critical temperature and 24.8 ± 0.5 MPa for the critical pressure. The critical vapor pressure measured by Bhise and Bonilla using a pressure tube method is 25.64 MPa. This measured value is higher than the extrapolated value given by Binder. The lower critical temperature given by Binder is consistent with his lower critical pressure. Freyland and Hensel[18] determined high temperature/pressure properties of potassium using the same technique used by Binder. In their analysis of the potassium vapor pressure data and critical parameters, Browning and Potter[1] found that the critical temperature and pressure determined by Freyland and Hensel from their superheated sample were inconsistent with critical parameters determined experimentally by others and also inconsistent with the equation that fit available vapor pressure data for potassium. Comparison of values for the vapor pressure calculated with the linear equation of Binder with values from the recommended equation (Browning and Potter's Eq. [10]) and from recommended equations from other assessments indicates that the values from Binder's extrapolation are consistently high. Binder's values and those of the recommended equation as well as values from other assessments are shown in Fig. 1.2-4. Differences from the recommended equation expressed as a percent are shown in Fig. 1.2-5. These comparisons indicate that the vapor pressure equation and critical parameters suggested by Binder are inconsistent with other sodium data. Consequently, the equation recommended for the vapor pressure of sodium does not include the Binder data.

The pressure of 25.64 MPa at the critical point was determined experimentally by Bhise and Bonilla.[8] The recommended equation from Browning and Potter's analysis of the vapor pressure data in the temperature range of 864 to 2499 K gives a critical temperature of 2503.7 K for the critical pressure of 25.64 MPa. Bhise and Bonilla[8] had fit their high temperature data, $T > 2350$ K, to a linear equation and obtained a critical temperature of 2507.6 K for the critical pressure 25.64 MPa. Das Gupta et al.[19] reanalyzed the experimental data of Bhise and Bonilla. They retained 25.64 MPa for the critical pressure and suggested 2508.7 ± 12.5 K for the critical temperature. Browning and Potter[1] also analyzed the Bhise and Bonilla high temperature data using a three-term equation and obtained 2507.1 K for the critical temperature, which is almost identical to the Bhise and Bonilla value. However, when their high temperature data are included with other available vapor pressure data, critical temperatures around 2503 K are obtained. Bystrov et al.[11] recommend 2503 K for the critical temperature.

Some assessments of the critical temperature of sodium suggest a value 100 to 200 K higher than the value implied from the pressure measurements of Bhise and Bonilla.[8] Petiot and Seiler[20] recommend a critical temperature of 2630 ± 50 K based on their analysis of vapor pressure and vapor density measurements to 2250 K. However, this value for the critical temperature is not consistent with the measured critical pressure of 25.64 MPa. The vapor pressure curve of Petiot and Seiler gives 2480 K as the temperature at which the vapor pressure equals 25.64 MPa, which is within the 50 K uncertainty of the temperature given by Browning and Potter's equation for that pressure. If the critical pressure of 34 ± 4 MPa, suggested by Petiot and Seiler, is used in the equations of Browning and Potter, a temperature of about 2660 K is obtained; this temperature is close to that given by Petiot and Seiler. Thus, the vapor pressure equations given by Petiot and Seiler and by Browning and Potter are consistent. The analyses differ in their choice of critical temperature. The higher critical temperature is not consistent with the measured critical vapor pressure of Bhise and Bonilla.[8] This is the only measured critical parameter. Thus, Browning and Potter's selection of

25.64 MPa for the critical pressure and the corresponding critical temperature of around 2503 K is reasonable in terms of experimental data presently available.

Uncertainty

The uncertainties in the recommended values, shown in Table 1.2-2, arise from three sources: (1) the statistical fit by Browning and Potter to the experimental data; (2) uncertainties due to differences between recommended equations by various analyses; and (3) experimental errors. These sources of error are discussed below in the order given. These discussions are followed by an estimate of the uncertainties as a function of temperature from all three sources of error.

Equation (3) gives the uncertainties for each of the coefficients in Eq. (1). These uncertainties were obtained from the statistical least squares fit by Browning and Potter of the data shown in Table 1.2-3:

$$\ln P = 11.9463 \pm 0.5127 - (12633.73 \pm 90.524)/T - (0.4672 \pm 0.0616) \ln T \quad . \tag{3}$$

In Eq. (3), pressure *(P)* is in MPa and temperature *(T)* is in K.

Comparison of the vapor pressures obtained from Eq. (1) with vapor pressures calculated using another equation recommended by Browning and Potter[1] and equations recommended by other analysts,[11-16] show differences on the order of 0.03% to 3% for the temperature range 864 to 2503.7 K. The greatest deviations between the recommended equations occur near the low temperature 864 K.

Because Browning and Potter included no low temperature data in their database, Eq. (1) is strictly valid only for the temperature range 864 to 2503.7 K. Values calculated using this equation below 864 K are extrapolations and, therefore, may have larger errors than values calculated above 864 K. Comparison of extrapolated values with values from other equations show good agreement with the values given by equations recommended by Bystrov et al.[11] and by Vargaftik and Voljak.[12] However, values of the vapor pressure obtained by extrapolation of Eq. (1) to 400 K differ by 24% from values calculated using the equation recommended in the assessment of sodium properties for LMFBR safety.[13-15] However, values at higher temperatures are in good agreement. The equation recommended in the LMFBR safety analysis was based on a fit to the high temperature data of Bhise and Bonilla,[8] the intermediate temperature data of Stone et al.,[7] and the low temperature data (melting point to 1155 K) of Ditchburn and Gilmour.[17] Both the Bhise and Bonilla data[8] and that of Stone et al.[7] were included in the assessment by Browning and Potter.

However, the Ditchburn and Gilmour data were not included in the Browning and Potter analysis nor in the analyses for the equations recommended by Bystrov et al.(11) and by Vargaftik and Voljak.(12) The large deviation at 400 K between the equation recommended for LMFBR safety analysis(13-15) and Eq. (1) is most likely due to inclusion of the low-temperature data of Ditchburn and Gilmour in the LMFBR safety analysis.

Bystrov et al.(11) have examined the errors in the experimental data above 1000 K. They report experimental errors of 1% for the temperature range 1000 to 1500 K, 2-3% up to 2000 K, and 4-5% at the higher temperatures.

Uncertainties in the recommended values have been estimated from the error in the statistical analysis, the error in the experimental data (given by Bystrov et al.(11)), and the deviations between recommended equations. In the calculation of uncertainties, the errors from these sources have been assumed to be independent so that the overall uncertainty is the square root of the sum of the squares of the statistical, experimental, and fitting uncertainties. Estimated uncertainties are tabulated as a function of temperature in Table 1.2-2. The recommended equation derived from data for the temperature range 864 to 2499 K, but suggested for the entire temperature range, is included in Table 1.2-2. The uncertainties expressed as a percent are large for the low temperatures due to the large percent deviation in the vapor pressures calculated using different equations. Because the vapor pressure is so low at these low temperatures, the difference in vapor pressure between the equations is very small (4×10^{-12} MPa at 400 K) even though the percent deviation is large.

<u>Polynomial Approximation</u>

In some applications such as the SASS code,(22) the equation for the vapor pressure must be inverted, so that temperature *(T)* is expressed as a function of saturation pressure *(P)*. Because the recommended equation cannot be inverted, the recommended values for the natural logarithm of the vapor pressure have been fit to a polynomial of the form used in the SASS code:(22)

$$\ln P = A - \frac{B}{T} - \frac{C}{T^2} \tag{4}$$

Then *T*, is related to *P* by

$$T = \frac{2C}{-B + \sqrt{B^2 + 4AC - 4C \ln P}} \quad . \tag{5}$$

Approximating the natural logarithm of the pressure (ln P) with the polynomial given in Eq. (4) creates systematic errors due to differences in the functional forms. If the fit to Eq. (4) is done by minimizing χ^2, then the coefficients in Eq. (4) are given by

$$A = 7.8270 \ ,$$
$$B = 11275 \ ,$$
$$C = 4.6192 \times 10^5 \ .$$

Deviations of Eq. (4) from Eq. (1) expressed as a percent given by

$$Deviation = \left(\frac{[Eq.\ (4) - Eq.\ (1)]\,100\%}{Eq.\ (1)} \right) \tag{6}$$

vary for this fit from a minimum of 0.03% to 1.7%, as shown by the "xhisq" curve in Fig. 1.2-6. In Fig. 1.2-6, lines have been included to guide the eye between the points where the deviations were calculated. This fit gives a χ^2 of 0.0003. Minimizing the absolute value of the deviation defined in Eq. (6) gives a larger χ^2 (0.001) but does not give the large percent deviation at 1500 K. The fit based on minimization of the absolute value of Eq. (6) has the coefficients

$$A = 7.8130 \ ,$$
$$B = 11209 \ ,$$
$$C = 5.2490 \times 10^5 \ .$$

This fit, labeled abs(diff) in Fig. 1.2-6 is preferred because it has no large percent deviations at any points. Percent deviations are greatest at the two extremes (0.49% at 864 K and 0.25% at 2503.7 K). From the χ^2 for the two fits, shown in Fig. 1.2-7, it is clear that the larger χ^2 for this fit is due to the contributions to χ^2 from the two low temperature points (864 and 900 K). All other points have contributions similar to those for the χ^2 minimization. The lines in Fig. 1.2-7 are guides for the eye between the points.

1.2.2 BOILING POINT

Recommendation

The recommended value for the boiling point of saturated liquid sodium (liquid in equilibrium with its vapor) is 1154.7 ± 1.3 K. This is the temperature at which the vapor pressure, determined from Eq. (1), equals 1 atm (0.1013 MPa).

Discussion

Ohse et al.[(23)] list experiments designed to determine the boiling point of sodium. This list is given in Table 1.2-4, which also includes the boiling point, experimental method, and year of experiment. The boiling point of sodium determined from these experiments ranges from 1154.4 to 1156 K. Values for the boiling point of sodium given in recent assessments of vapor pressure and sodium property data are shown in Table 1.2-5 according to the year of assessment. Except for values given by Vargaftik[(34)] and by Cordfunke and Konings,[(36)] recommended boiling points are in the 1154 to 1156.5 K range.

The recommended value 1154.7 ± 1.3 K, from the equation given by Browning and Potter,[(1)] differs by 0.1 K from the value they give in their assessment. This is because Browning and Potter give the temperature at which the vapor pressure calculated via Eq. (2) is 1 atm, whereas the recommended value is based on Eq. (1). This difference is well within the 1.1 K uncertainty given by Browning and Potter. An uncertainty of 1.3 K is given for the recommended value so that the uncertainty includes the extremes in values from the experiments.

Table 1.2-4 Measured Boiling Point of Sodium*

T_b, K	Measurement Method	Authors	Year	Ref.
1156	Vapor Pressure	Heycock & Lamplough	1912	24
1156	Vapor Pressure	Ladenburg & Thiele	1930	25
1154.5	Vapor Pressure	Makansi et al.	1955	6
1154.52	Vapor Pressure	Bonilla et al.	1962	26
1156	Vapor Pressure	Sowa	1963	9
1154.59	Vapor Pressure	Bowles & Rosenblum	1965	27
1150.15	Vapor Pressure	Achener et al.	1966	4
1154.6	Vapor Pressure	Stone et al.	1966	7
1156.0	State Equilibrium	Vinogradov & Voljak	1966	10
1154.4	Vapor Pressure	Fischer	1966	28
1156.	Vapor Pressure	Bohdansky & Shins	1967	2
1155.5	Vapor Pressure	Achener et al.	1967	29
1155.12	Heat Pipe	Schins et al.	1971	3
1155.2	Pressure Tube	Bhise & Bonilla	1977	30
1154.6	Vapor Pressure	Das Gupta	1977	31

*Table is from Ohse et al.[22]

Table 1.2-5 Boiling Points of Sodium Recommended in Assessments

T_b, K	Author	Year	Ref.
1154.7	Shpil'rain	1970	32
1156	Hultgren et al.	1973	33
1151	Vargaftik	1978	34
1156.5 ± 1.1	Fink & Leibowitz	1979	13-15
1154	Thurnay	1981	16
1156	Chase et al.	1985*	35
1154.5 ± 1.0	Ohse et al.	1985	22
1154.8 ± 1.1	Browning & Potter	1985	1
1158	Cordfunke & Konings	1990	36
1156.3 ± 1.0	Bystrov et al.	1990	11

*Data assessment done in 1962.

1.2.3 ENTHALPY OF VAPORIZATION

Summary

Recommended values for the enthalpy of vaporization of sodium, shown in Table 1.2-6, have been calculated from

$$\Delta H_g = 393.37 \left(1 - \frac{T}{T_C}\right) + 4398.6 \left(1 - \frac{T}{T_C}\right)^{0.29302} \tag{7}$$

$$for\ 371\ K \leq T \leq 2503.7\ K\ ,$$

where enthalpy of vaporization (ΔH_g) is in kJ·kg^{-1}, temperature *(T)* is in kelvins, and T_C = 2503.7 K, the critical temperature. Equation (7) is a fit to values of the enthalpy of vaporization from 371 to 1600 K calculated using the quasi-chemical method developed by Golden and Tokar.[37] The form of equation used to fit these data gives the correct behavior at the critical point and is, therefore, suitable for extrapolation above 1600 K. Values calculated with Eq. (7) are in good agreement

Table 1.2-6 Enthalpy of Vaporization of Sodium

Temperature (K)	**$kJ \cdot kg^{-1}$**
371	4532
400	4510
500	4435
600	4358
700	4279
800	4197
900	4112
1000	4025
1100	3933
1200	3838
1300	3738
1400	3633
1500	3523
1600	3405
1700	3279
1800	3143
1900	2994
2000	2829
2100	2640
2200	2418
2300	2141
2400	1747
2500	652
2503.7	0

with values recommended by Fink and Leibowitz,[13-15] values recommended by Bystrov,[11] and values calculated with the equation recommended by Das Gupta.[31]

The recommended values of the enthalpy of vaporization are shown in Fig. 1.2-8. Uncertainty bands have been included up to 2400 K on the graph. Above 2400 K, the uncertainty in the critical temperature results in large uncertainties (30%) because the enthalpy of vaporization must be zero at the critical temperature. Uncertainties are given in Table 1.2-7 at a number of temperatures. Between the temperatures shown in Table 1.2-7, the uncertainties are assumed to vary linearly with temperature.

Table 1.2-7 Estimated Uncertainty in Values of the Enthalpy of Vaporization of Sodium Calculated from Eq. (7)

Temperature (K)	**Enthalpy of Vaporization (ΔHg, $kJ \cdot kg^{-1}$)**	**Uncertainty (%)**
371 - 1000	$\Delta H = 393.37 \left(1 - T/T_C\right) + 4398.6 \left(1 - T/T_C\right)^{0.29302}$	1
1400		2
1800		6.5
2000		7.3
2400		9.5

T_C = 2503.7K

Discussion

The quasi-chemical method[37] was used to calculate the enthalpy of vaporization from the melting point through 1600 K. The upper limit was chosen based on Padilla's[38] recommendation of 1644 K as the limit of validity of application of the quasi-chemical method to sodium. In the quasi-chemical method, the heat of vaporization is defined as

$$\Delta H_g = \left[\frac{N_1 \Delta H_1 + N_2 \Delta H_2 + N_4 \Delta H_4}{22.98977 \left(N_1 + 2N_2 + 4N_4\right)}\right] , \tag{8}$$

where N_1, N_2, and N_4 are, respectively, the mole fractions of the monomer, dimer, and tetramer; and ΔH_i is the contribution to the enthalpy of vaporization for each species. The gram molecular mass of the monomer, 22.98977, is the value recommended by CODATA.[39] The contributions to the enthalpy of vaporization for the monomer, dimer, and tetramer in $J \cdot mol^{-1}$ are, respectively;

$$\begin{aligned} \Delta H_1 &= 107844 - 14.4203T + 7.05130 \times 10^{-3} T^2 \\ &\quad - 2.57107 \times 10^{-6} T^3 + 14184 T^{-1} , \\ \Delta H_2 &= 2\Delta H_1 - 76584 , \\ \Delta H_4 &= 4\Delta H_4 - 173544 . \end{aligned} \tag{9}$$

The mole fractions of the monomer, dimer, and tetramer were calculated by solving the following set of equations:

$$\begin{aligned} N_1 + N_2 + N_4 &= 1 \ , \\ N_2 &= \alpha^2 P \left(N_1 + 2N_2 + 4N_4\right)^2 k_2 \ , \\ N_4 &= \alpha^4 P^3 \left(N_1 + 2N_2 + 4N_4\right)^4 k_4 \ , \end{aligned} \tag{10}$$

where α is the unassociated fraction of one mole of monomer

$$\alpha = \left(\frac{N_1}{N_1 + 2N_2 + 4N_4} \right) \ . \tag{11}$$

The equilibrium constants, k_2 and k_4, were determined experimentally by Stone et al.[40] Their natural logarithms, as reported by Stone et al., are represented by

$$\begin{aligned} \ln k_2 &= -9.95845 + \left(\frac{16588.3}{T_R} \right) \ , \\ \ln k_4 &= -24.5912 + \left(\frac{37589.7}{T_R} \right) \ , \end{aligned} \tag{12}$$

where T_R is the temperature in Rankins. The pressure *(P)* in Eq. (10) is given by Eq. (1).

Values of the enthalpy of vaporization from 371 through 1600 K, calculated using Eqs. (8-12) were fit by Eq. (7), which has an appropriate form for proper behavior at the critical temperature. Thus, a single equation suitable for the entire liquid temperature range was obtained.

Figure 1.2-9 shows the recommended equation for the enthalpy of vaporization of sodium and values from 800 to 2000 K given by Bystrov et al.,[11] values from 400 to 2400 K recommended by Fink and Leibowitz,[13-15] and values from 400 to 2400 K from the equation given by Das Gupta.[31] Values from assessments by Bystrov et al., Fink and Leibowitz, and Das Gupta are in good agreement with each other and with values from the recommended equation. Values recommended by Fink and Leibowitz were calculated using the quasi-chemical method to 1644 K and using an empirical equation to extrapolate from 1644 K to the critical temperature of 2509.46 K. Values given by Bystrov et al. are from their equation of state for sodium vapor which assumed that the vapor is composed of monomers, dimers, and positive ions. Das Gupta fit the enthalpy of vaporization data of Achener and Jouthas[4] (867 to 1202 K) and values obtained by application of the Clausius-Clapeyron equation to the data of Stone et al.[7] He recommended the equation

$$\Delta H_g = -1011.3 \left(1 - \frac{T}{T_C}\right) + 5689.1 \left(1 - \frac{T}{T_C}\right)^{0.4} \qquad (13)$$

for the entire temperature range. In Eq. (10), ΔH_g is in kJ·kg^{-1}, T is in K, and the critical temperature, T_C, is 2509.46 K.

Deviations from the recommended equation (Eq. [7]), expressed as percents, defined as

$$\frac{\left[\ \Delta H_g(Other) - \Delta H_g(Eq.\ 7)\ \right]100\%}{\Delta H_g(Eq.\ 7)} \quad ,$$

are shown in Fig. 1.2-10. For temperatures equal or less than 2100 K, deviations are 2% or less. Deviations become large as the critical temperature is approached because the enthalpy of vaporization must be zero at the critical temperature and different values were selected for the critical temperature in the different assessments.

Uncertainty

Uncertainties based on experimental measurements are not available for the enthalpy of vaporization. Estimated uncertainties for the enthalpy of vaporization calculated with Eq. (7) are given in Table 1.2-7 for various temperatures. Uncertainties are assumed to increase linearly with temperature between the temperatures given in Table 1.2-7. These uncertainties have been estimated from errors given by Bystrov et al.[11] and from deviations in values calculated using equations from a number of recent data assessments.

Errors given by Bystrov et al. include inaccuracies in the equation of the saturation curve, errors due to nonideality of the vapor, and differences between Bystrov's recommended values and the data of Achener and Jouthas.[4] Bystrov et al. give errors of 0.3% at 1000 K, 0.4% at 1400 K, and 6.5% at 1800 K. Estimated uncertainties given here for temperatures below 1800 K are greater than those given by Bystrov et al.[11] because deviations from the various accepted equations differ by 1% below 1000 K and by 2% at 1400 K.

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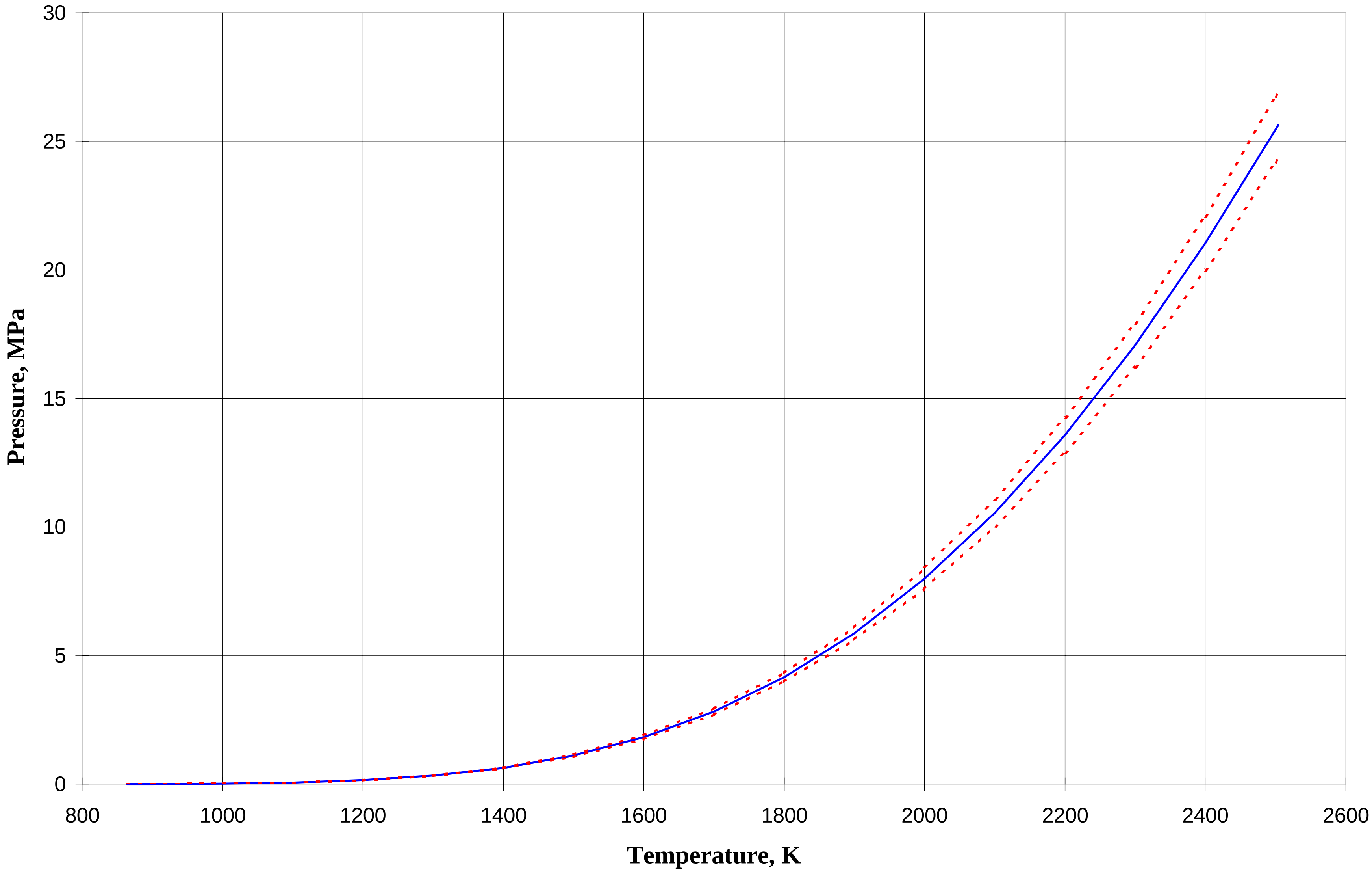

Fig. 1.2-1 The Vapor Pressure of Saturated Sodium

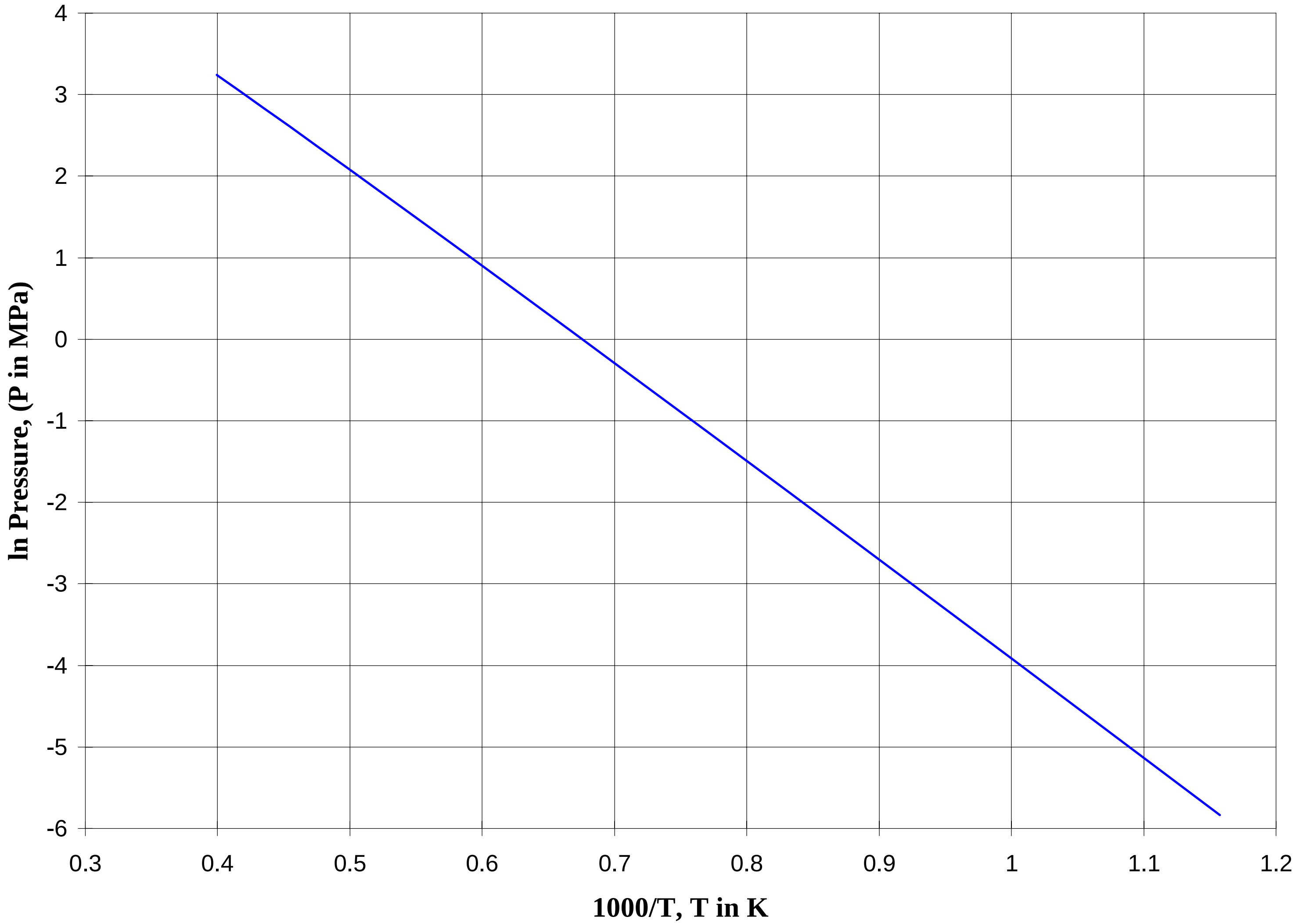

Fig. 1.2-2 The Natural Logarithm of Sodium Vapor Pressure as a Function of Inverse Temperature

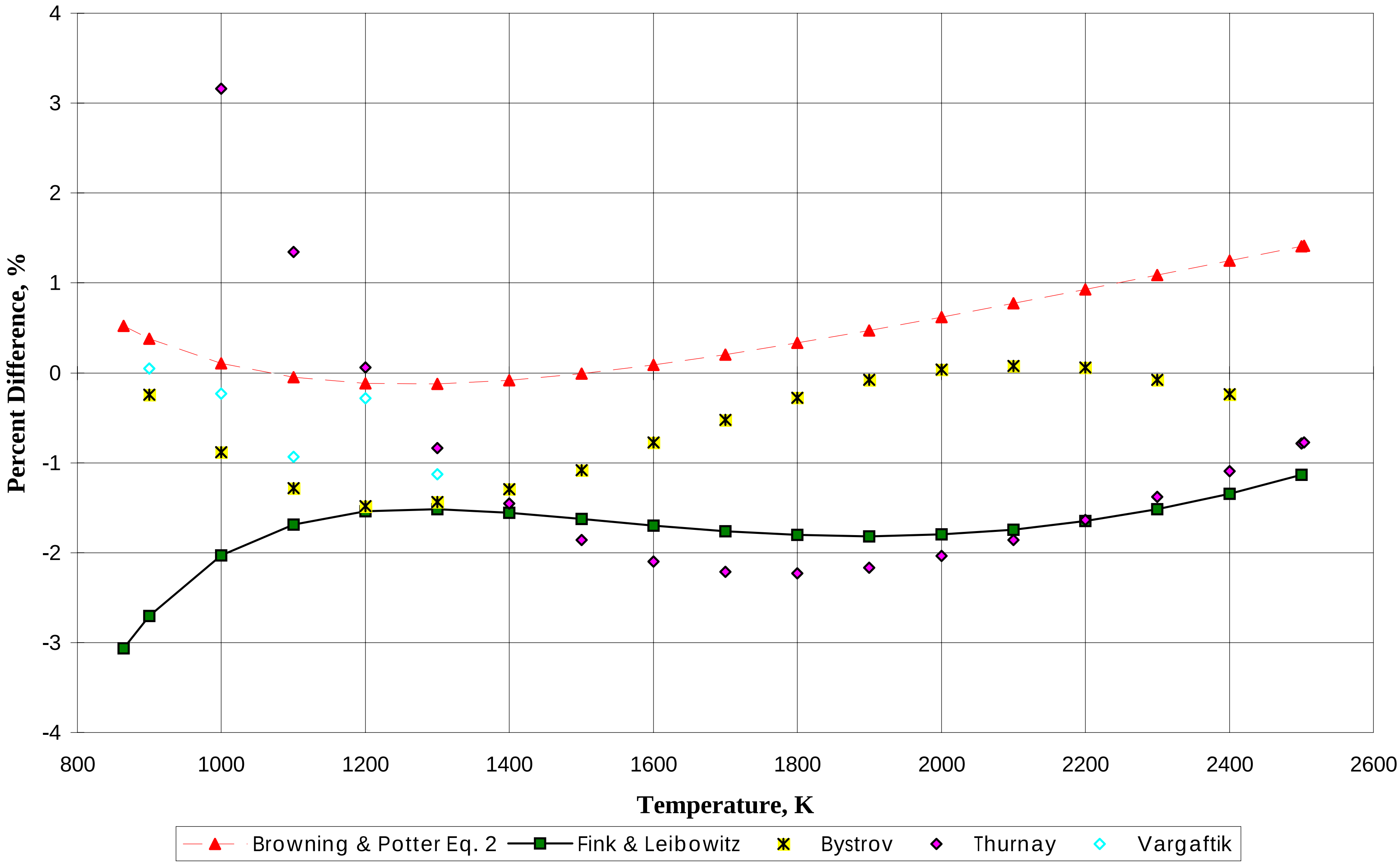

Fig. 1.2-3 Deviation of Other Vapor Pressure Equations from the Recommended Equation

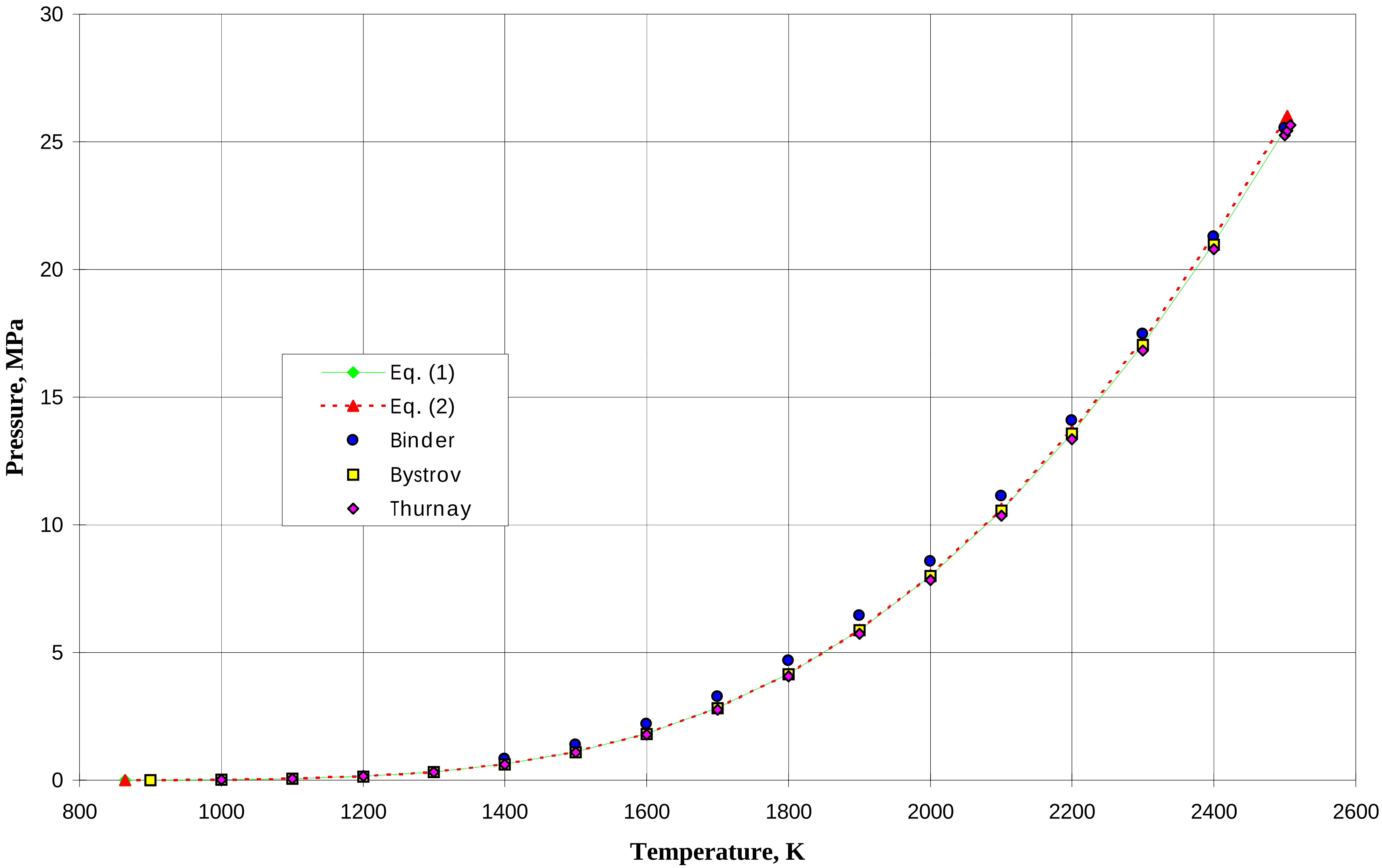

Fig. 1.2-4 Vapor Pressures Calculated from Various Recommended Equations

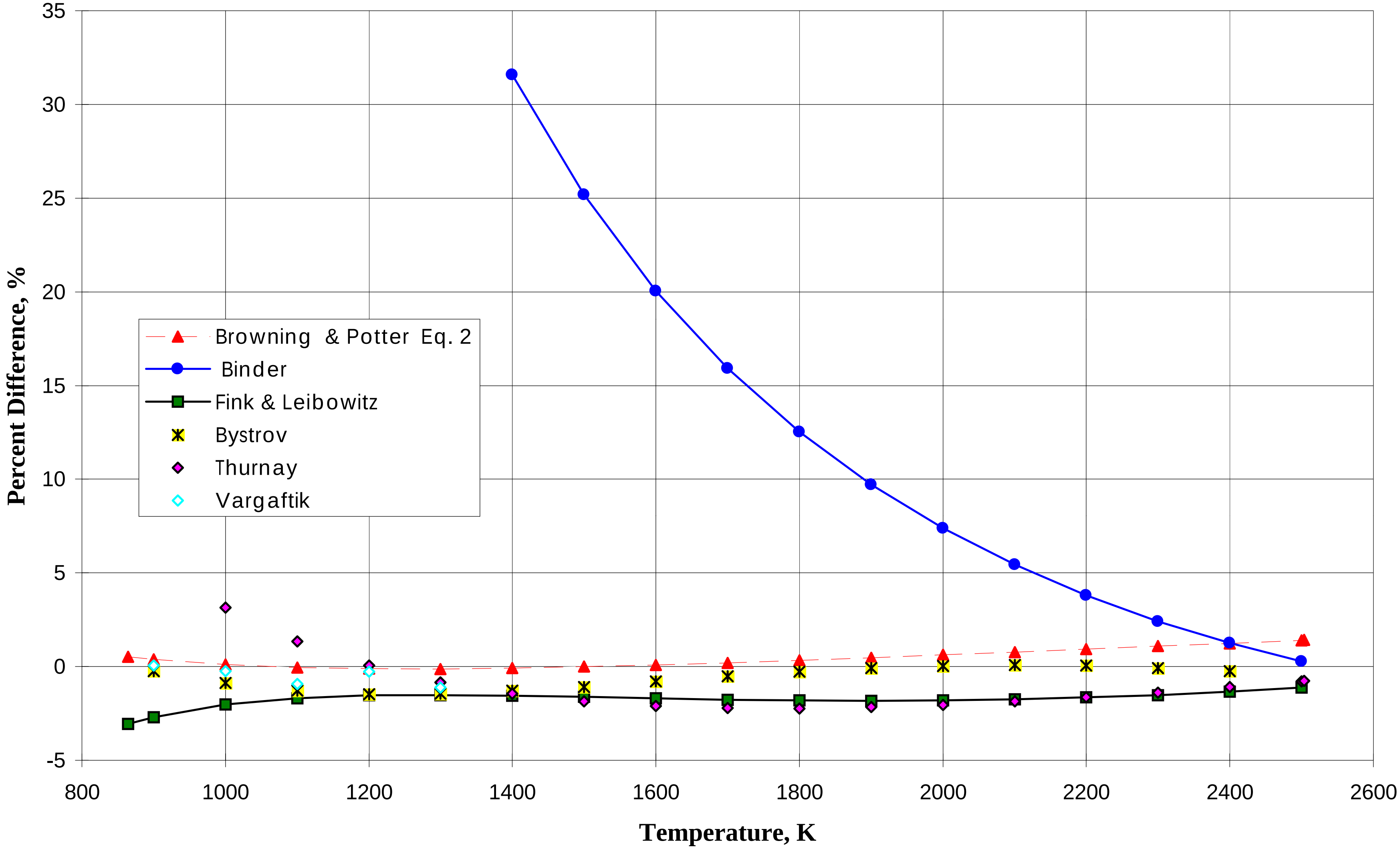

Fig. 1.2-5 Deviation of Binder's Vapor Pressure Equation from the Recommended Equation Compared with Deviations from Other Assessments

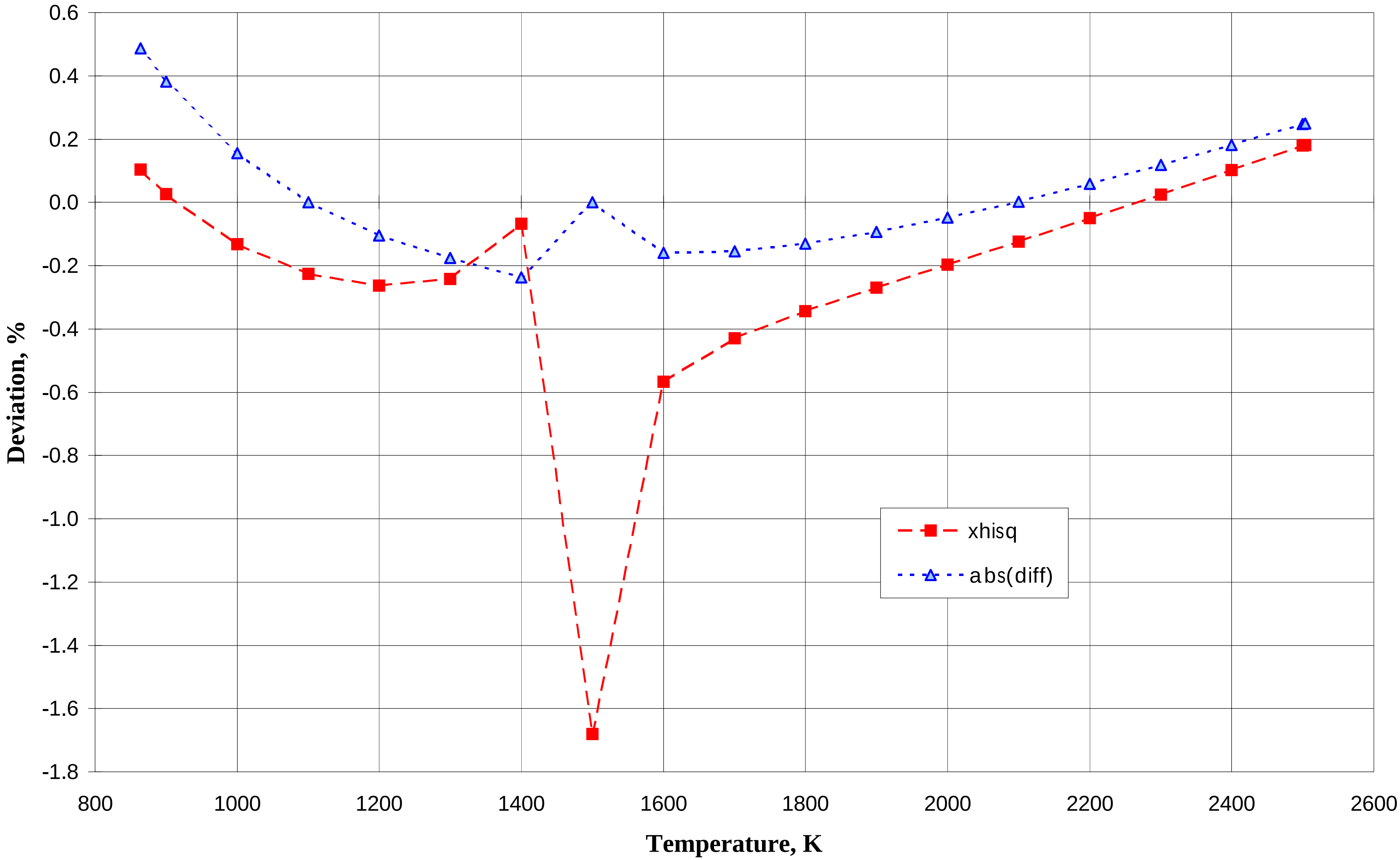

Fig. 1.2-6 Percent Deviation for Two Fits to ln P Using Eq.(4) "xhisq" Minimizes X^2; "abs(diff)" Minimizes the Absolute Value of the Deviation Defined in Eq. (6)

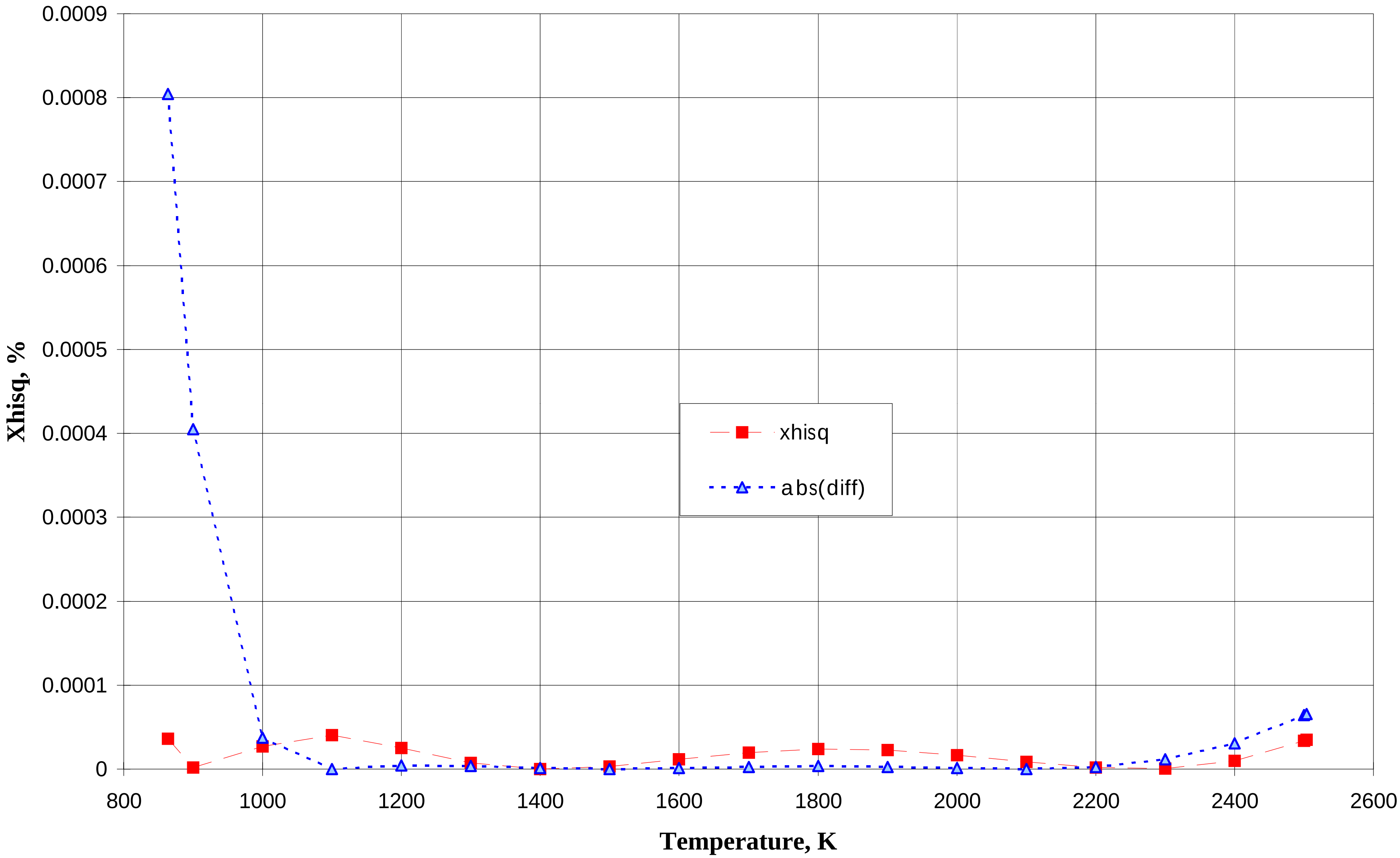

Fig. 1.2-7 X^2 of Eq.(4) fits to ln P Using Two Minimization Techniques: "xhisq" Minimizes X^2; "abs(diff)" Minimizes the Absolute Value of the Deviation in Eq.(6)

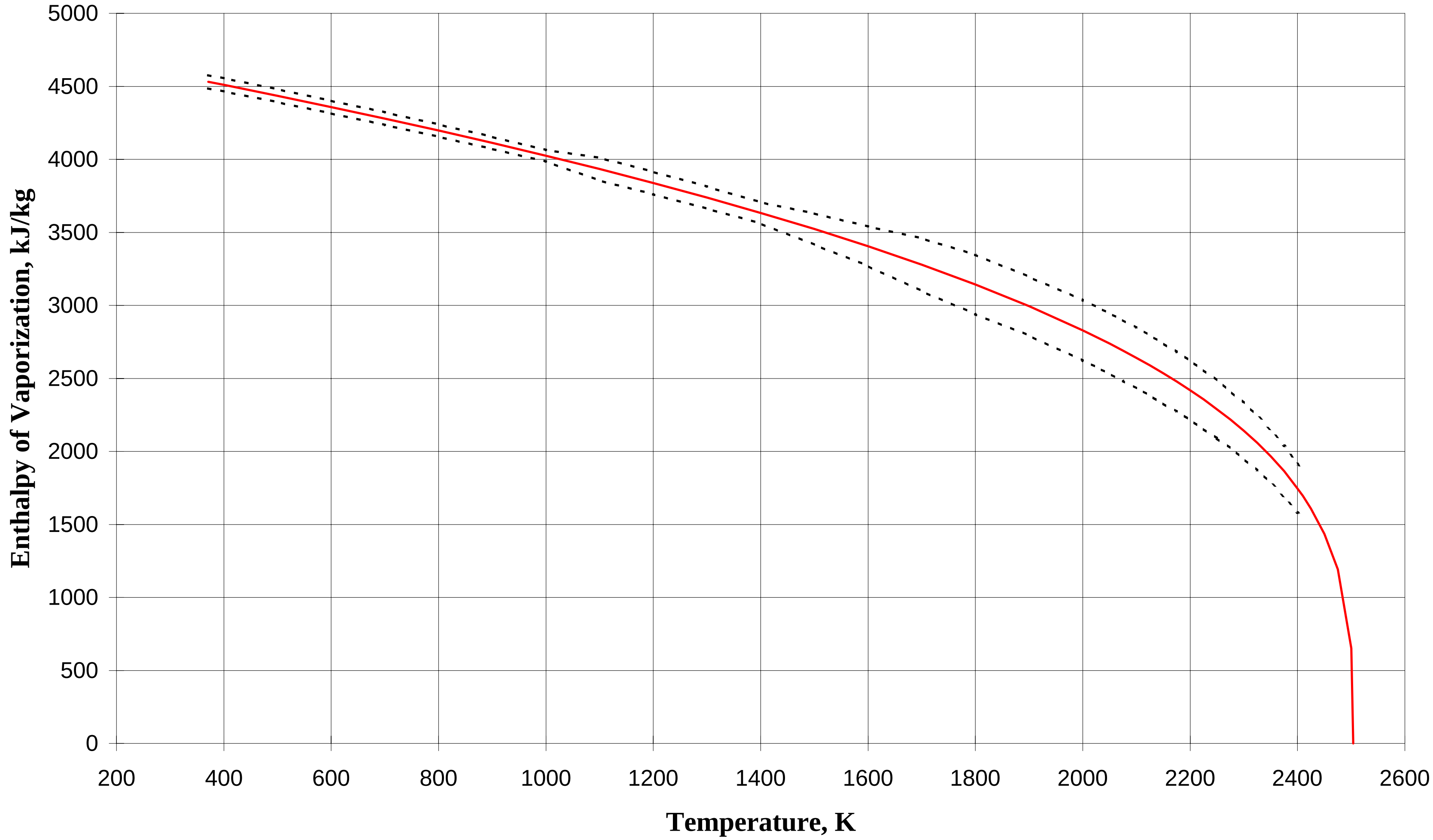

Fig. 1.2-8 Recommended Values of Enthalpy of Vaporization of Sodium (Dashed Lines Show the Estimated Uncertainty)

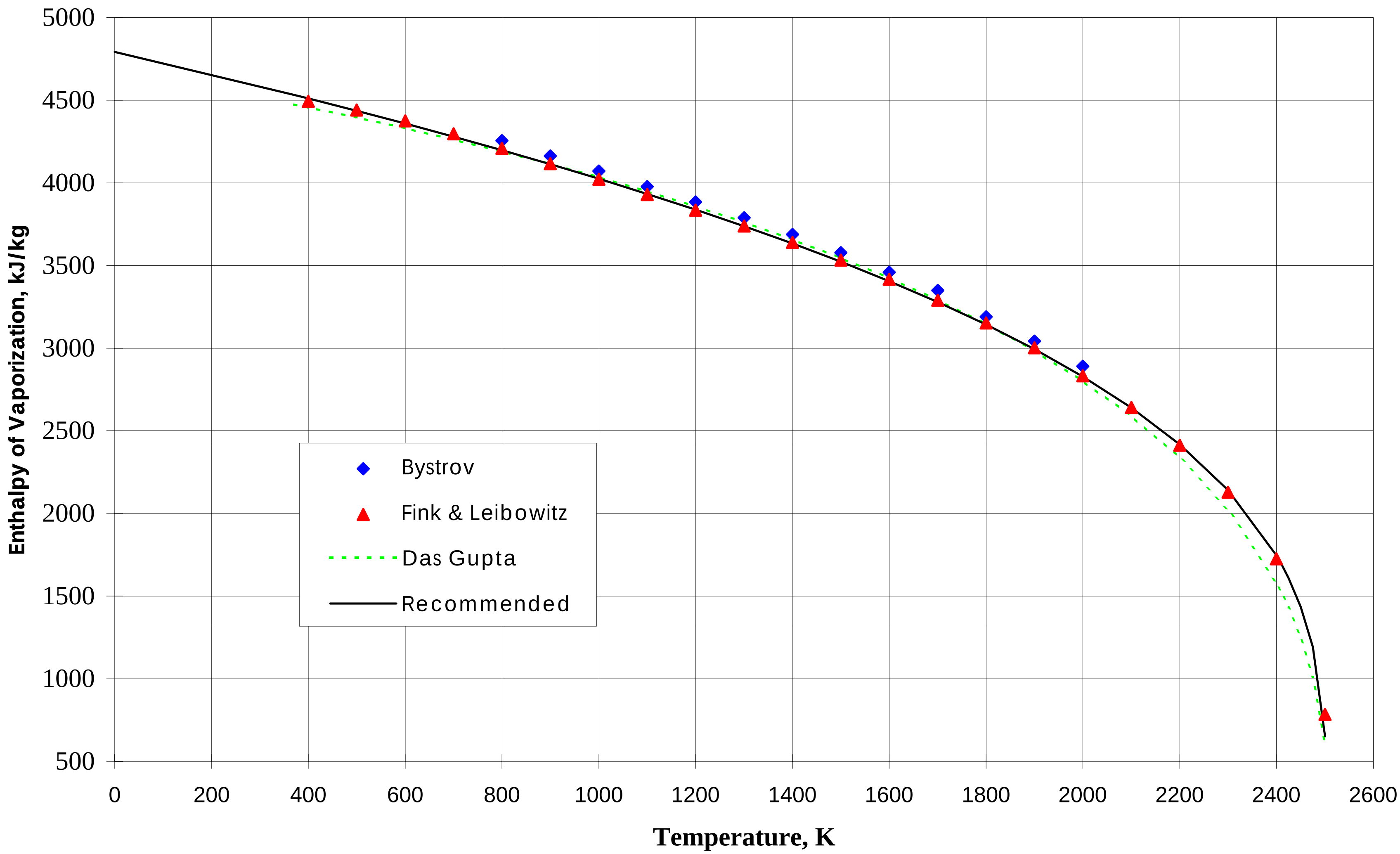

Fig. 1.2-9 Comparison of Recommended Equations for Enthalpy of Vaporization of Sodium with Values from Other Assessments

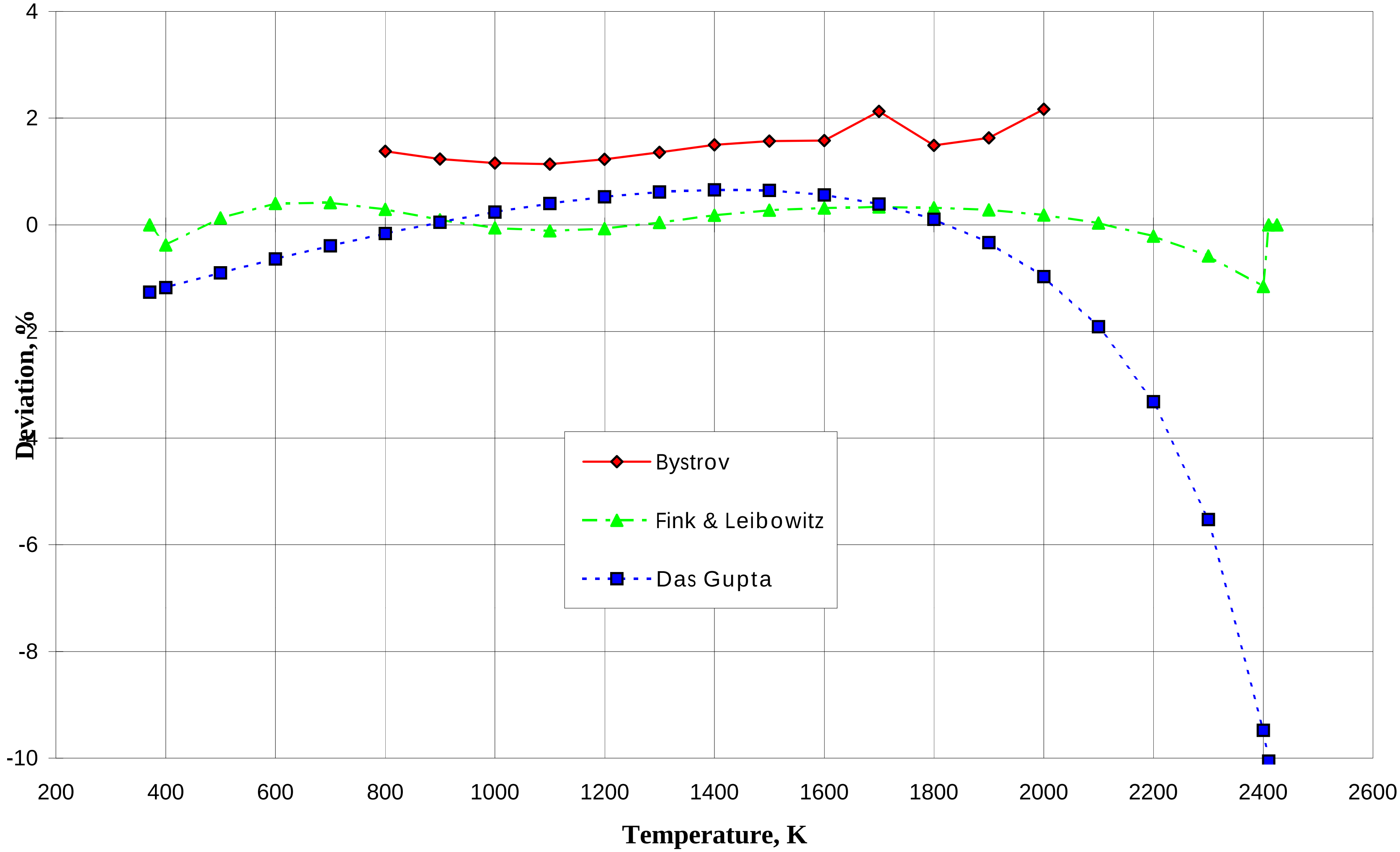

Fig. 1.2-10 Deviations of Values from Other Assessments from Recommended Values of the Enthalpy of Vaporization of Sodium

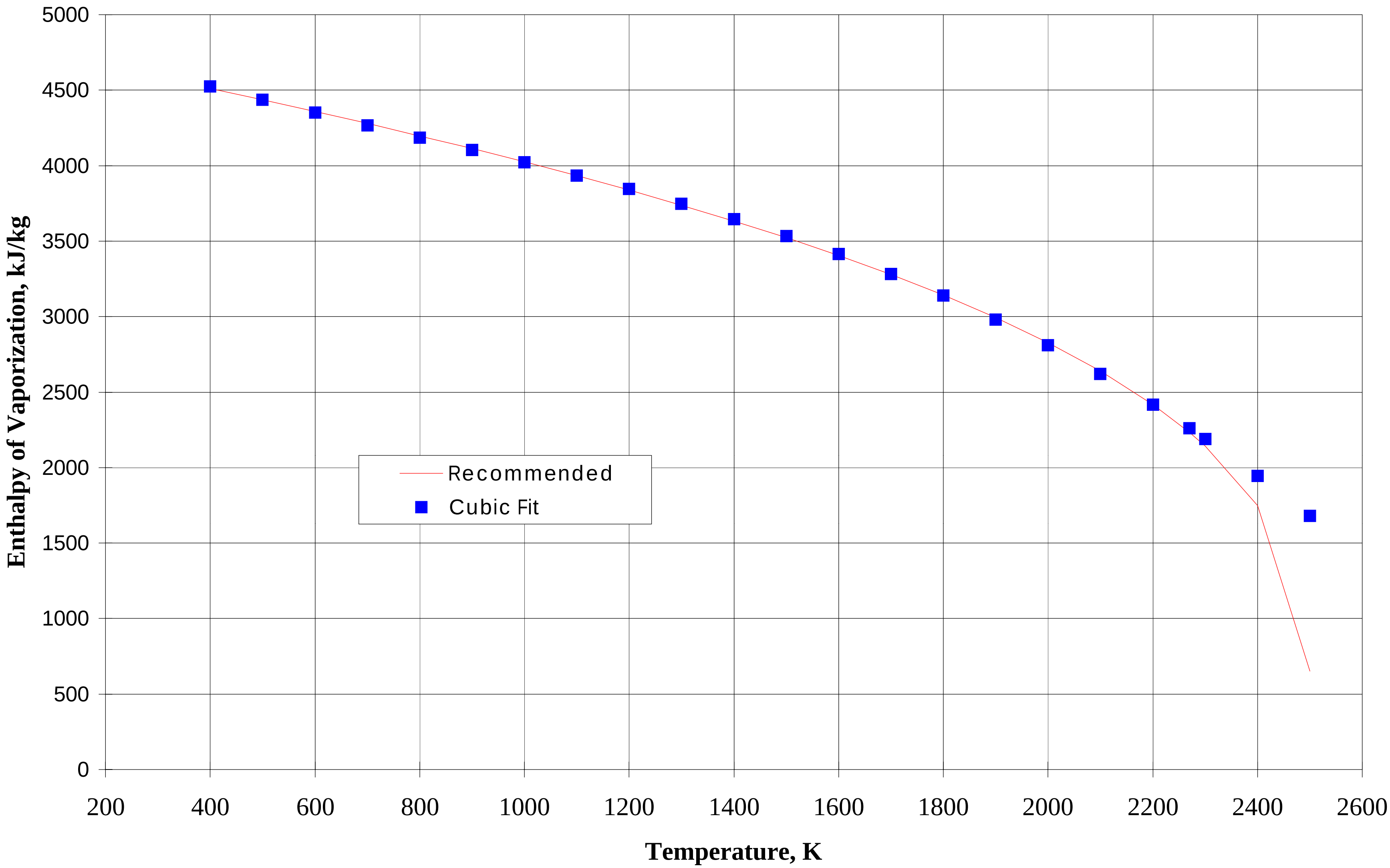

Fig. 1.2-11 Comparison of the Cubic Fit from the Recommended Values for the Enthalpy of Vaporization of Sodium

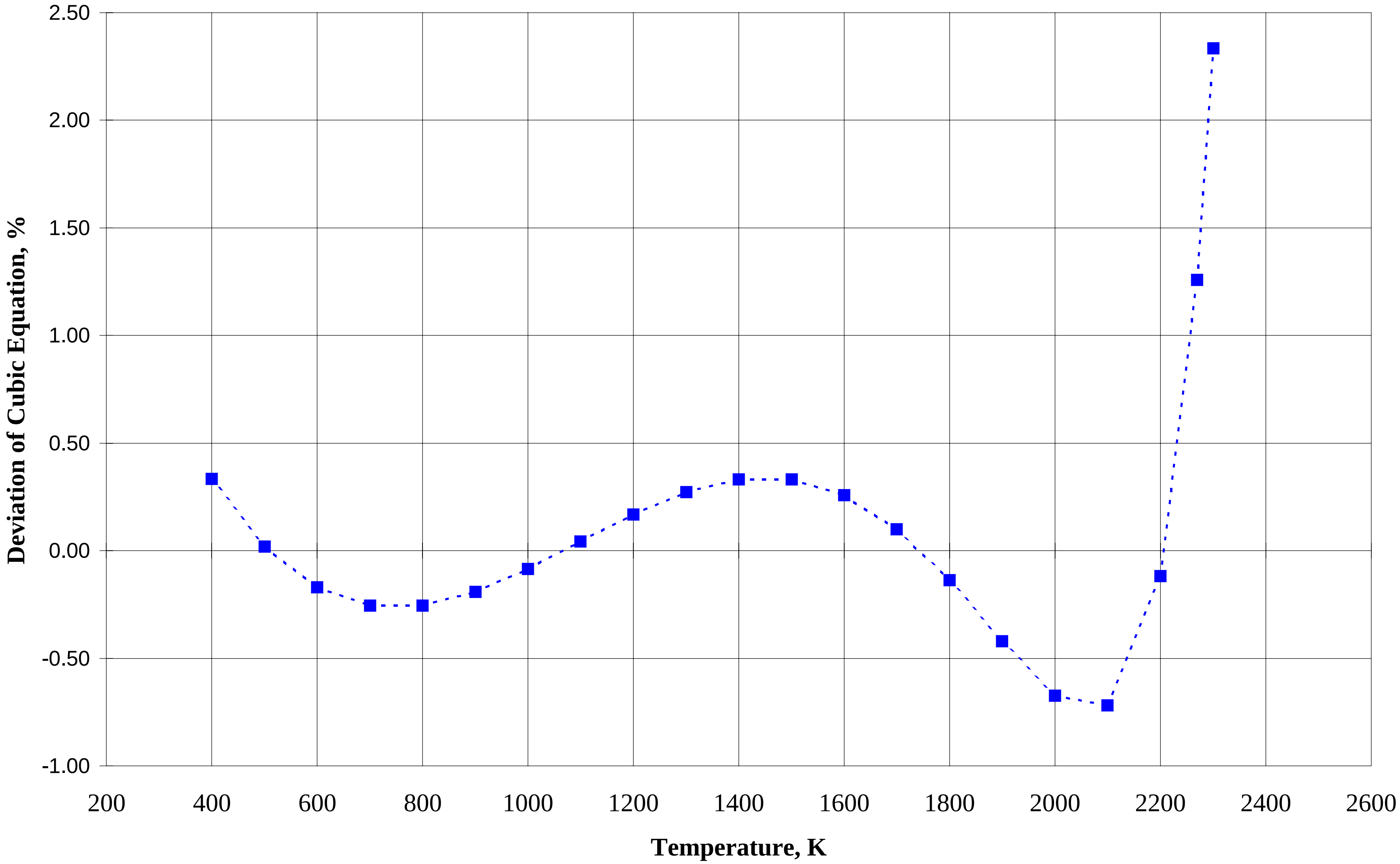

Fig. 1.2-12 Deviations of Values from the Cubic Fit from Recommended Values of the Enthalpy of Vaporization of Sodium